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Raspberry-Pi Zero-Based Reflection Seismic Logger Design with Network Time Protocol Synchronization

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ABSTRACT

As a country, Indonesia has a very high mineral reserve potential. Non-tax state revenue also contributes from the mining sector. Efforts to explore the content of minerals in the earth's bowels can use the seismic reflection method. This seismological principle relies on the propagation of mechanical waves whose reflections are captured and recorded using a geophone. Limitations of domestically produced seismic instrumentation can slow down exploration activities.
For this reason, developing domestic geo-seismic acquisition instrumentation is necessary to support exploration activities. In this study, eight units of a Raspberry Pi-based reflection seismic logger prototype device have been made using the MEMS ADXL355 accelerometer sensor with NTP protocol synchronization. Data from the initial test results show that the eight seismic reflection loggers of the device can work simultaneously in reading the seismic waves they receive.

Keywords: *Mineral Exploration, Reflection Seismic, Logger Device, Raspberry-Pi Zero, Network Time Protocol Synchronization.*

1. INTRODUCTION

One of the countries with very high mineral reserve potential was Indonesia. For example, Indonesia occupies the top third position globally in nickel minerals. A contribution of 39% for gold products recorded came from Indonesia, in second place after China. It makes Indonesia always become one of the top 10 in the world [1]. The enormous potential non-tax state revenue contributes from the mining sectors. The sustainability principles in natural resources utilization for the greatest prosperity of the people and the achievement of Sustainable Development Goals (SDGs) are applied as a reference for mining companies [2].

Through the Geological Agency of the Ministry of Energy and Mineral Resources (BG-ESDM), Indonesia continues to carry out an inventory and explore potential natural resources that are still stored [3]. It includes oil and natural gas (oil and gas), minerals and coal, geothermal, to rare earth elements (REE). These findings will later be reported as state assets and used to increase revenues through mining products.

Efforts to explore the potential of mineral content in the earth's bowels are carried out using the seismic reflection method [4]. This method has several components, such as acoustic impedance, reflection coefficient, wavelets, and seismic resolution [5,6]. The workings of this method are to utilize reflected waves based on seismological principles (Figure 1).

This seismological principle relies on artificial mechanical waves, which are generally sourced from dynamite explosions, propagate through rocks in the ground, and will bounce back towards the surface after passing through the boundary of rock layers as a reflector field. The reflected waves are then captured and recorded using a geophone [7–13].

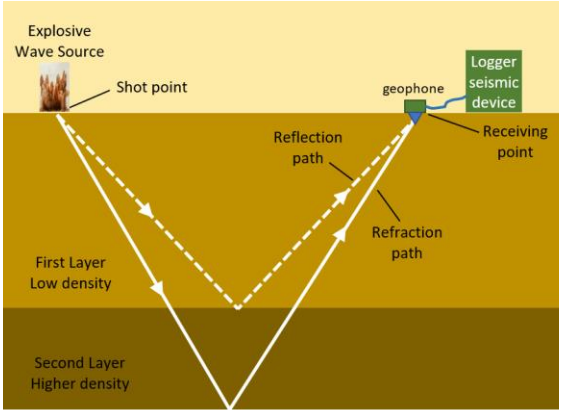

Figure 1. illustration of Seismic Reflection wave propagation.

Each rock layer beneath the earth's surface has different acoustic impedance characteristics (Figure 2) [14]. This impedance is influenced by the type of lithology, porosity, fluid content, rock depth, pressure, and medium temperature. Acoustic impedance is mathematically expressed as follows:

$$AI = \rho \cdot v \tag{1}$$

Where ρ is the density of the rock, and v is the propagation speed of acoustic waves in the rock medium.

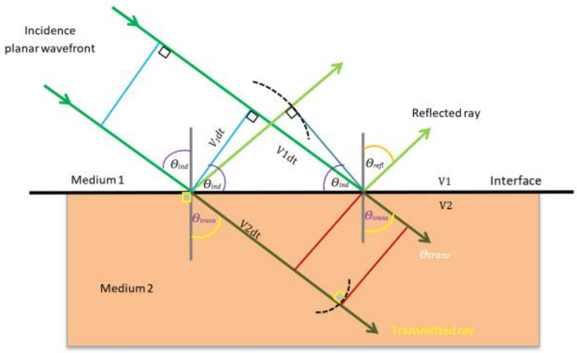

Figure 2. Acoustic Impedance mechanism.

The boundary medium between two rock layers is usually influenced by the sediment planes and the porosity characteristics of each layer. The difference in the density of the rock media and changes in the speed of wave propagation in it can be calculated using the Snell's Law formula approach [15], which are:

$$\frac{\sin \theta_i}{V_1} = \frac{\sin \theta_t}{V_2}$$

Where θ_i is the primary wave angle in medium 1, θ_t is the wave angle in medium 2, V_1 is the wave velocity in medium 1, and V_2 is the wave velocity in medium 2.

Reflection of seismic waves will appear every time there is a change in the acoustic impedance value. The comparison between the reflected energy and incident energy under normal circumstances is as follows:

$$\frac{E_{reflection}}{E_{Source}} = |KR|^2 \tag{2}$$

$$KR = \frac{(IA_2 - IA_1)}{(IA_2 + IA_1)} \tag{3}$$

Wavelets, commonly referred to as seismic signal waves, are a collection of seismic waves with a certain amplitude, frequency, and phase.

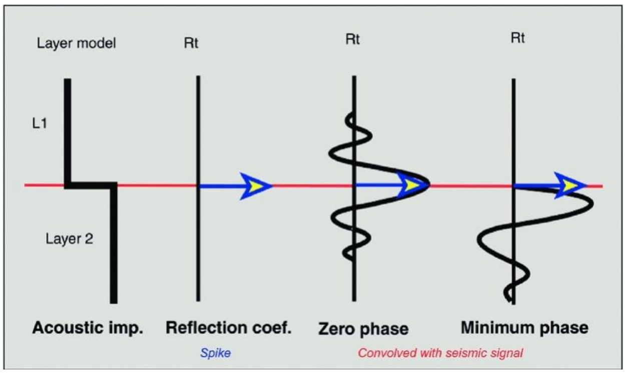

Figure 3. The shape of the seismic wave signal or wavelet.

Seismic resolution (vertical) is seismic acquisition's ability to separate and distinguish two vertical boundaries between rocks.

$$r_v = \frac{1}{4}\lambda = \frac{v}{4f} \tag{4}$$

Where r_v is the vertical resolution of the wave, λ is the wavelength (m), v is the average speed (m/s), and f is the frequency (Hz).

The minimum resolution a seismic wave can display is ¼ λ, known as the *tuning thickness*. On the horizontal wave, a resolution is an ability to acquire seismic waves to the difference between the two reflectors.

In general, seismic wave sensing activities use geo-seismic acquisition instrumentation imported from abroad. Limitations of domestic seismic instrumentation can be an obstacle to slow exploration activities. For this reason, it is necessary to develop geo-seismic acquisition instrumentation to support domestic exploration activities. For this reason, this research designed an alternative tool that can be used as geo-seismic acquisition instrumentation in the form of a Raspberry Pi-based seismic reflection logger with NTP protocol synchronization.

2. METHODOLOGY

2.1 Raspberry-Pi

In this study, the operating brain of the seismic logger instrumentation design is the Raspberry Pi Zero type. This device is a *Single Board Computer* (SBC) the size of a credit card that adopts the ARM11 architecture.

This Raspberry-Pi operating system uses Linux-based Raspbian developed by the British Raspberry Foundation. It supports many communication protocols such as UART, Modbus Serial, Modbus TCP/IP, and the Zero-types, which only have mini-USB and mini-HDMI as their communication ports [16].

Figure 4. Rapsberry-Pi Zero.

2.2 ADXL355 MEMS Vibration

To capture the reflection of seismic waves from within the earth, the design of this tool relies on a *Micro Electro Mechanical System* (EMS) sensor of the ADXL355 type, which works on 3 class C-axes (Figure 5).

Figure 5. ADXL355 analogue sensor.

This sensor uses an internal 20-bit ADC and a filter with a frequency of 0.005 to 25 Hz, which is equipped with a *Real Time Clock* (RTC) and has an offset of ±75 mg [17]. This tool is a high-performance MEMS with an accelerometer equipped with *Microcontroller Units* (MCU) which helps collect output data through the *Serial Peripheral Interface* (SPI). The ADXL355 MEMS accelerometer has a data range of ±2,048 g, ±4,096 g, and ±8,192 g under optimal conditions.

2.3 Battery Monitoring System (BMS)

The need for an electricity supply to operate the logger device is regulated by the *Battery Monitoring System* (BMS) module which is equipped with 8 of 18650 type batteries, with a capacity of around 3000 mAh each [18]. This module is designed to support logger device operation capability for three days. This module is equipped with an LCD screen that displays the amount of power stored in the battery and the amount of power consumed by the logger device.

2.3 NTP (Network Time Protocol)

This logger instrumentation design uses the *Network Time Protocol* (NTP) [17,19]. This protocol synchronizes the time on a computer system network of several connected device reflection seismic loggers (Figure 6). it is necessary to get an accurate time on each logger device.

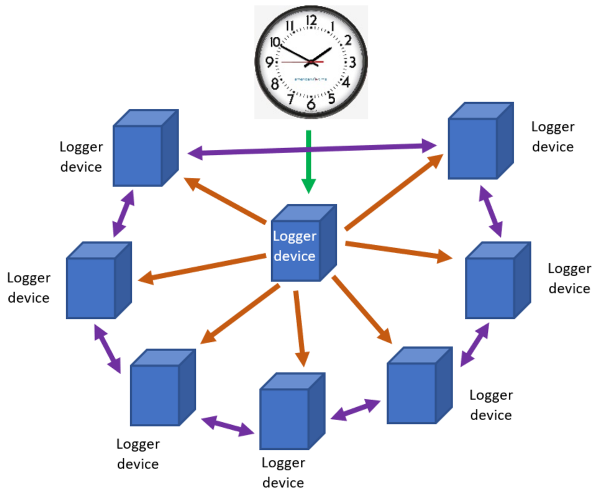

Figure 6. Illustration of Network Time Protocol (NTP).

2.4 Global Positioning System (GPS)

In order to identify the location for data collection for each receiving point, the *Global Positioning System* (GPS) module (Figure 7) is placed inside this device by utilizing the geographic coordinates read from the satellite [20–22].

Figure 7. Neo GPS Module.

2.5 Circuit Block Diagram

The logger seismic reflection device design concept is outlined in the form of a block diagram (Figure 8) before being made into a prototype. The block diagram consists of several parts, including:

1. The battery and BMS function as a power supply source and regulators of the power supply circulating current.
2. GPS functions as a position determinant and one of the system timing sources that time must synchronize based on the device's position.

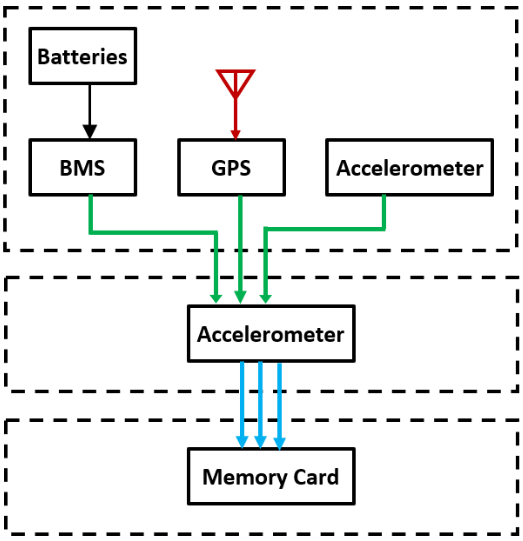

Figure 8. Seismic logger instrumentation block diagram.

1. The accelerometer sensor functions as a data source, namely vibration data from the ground, which will be processed on the Raspberry Pi.
2. The Raspberry Pi here functions as the system's brain, which will synchronize the timing between GPS and NTP and record and store data.
3. SD Card functions as a place to store data processed by the Raspberry Pi.

Based on the block diagram design, a prototype is made by arranging each module following the block diagram.

3. RESULTS AND DISCUSSION

3.1 Reflection Seismic Instrument Logger Manufacturing

The device's reflection seismic logger manufacturing process has been carried out. This activity produced eight units of seismic reflection logger devices with a box-shaped container equipped with an accelerometer sensor placed separately in a cone-shaped container. The central unit and the sensor housing are connected by a cable that is 2 meters long.

Figure 9. The eight seismic reflection logger units that have been made.

3.2 GPS Time Synchronization Process

Time synchronization of the Raspberry Pi seismic module with the Neo-6M GPS module is required to determine the surface contour and position of the modules.

The unification of time between the two is carried out in two stages. The first stage is the installation of the Neo-6M GPS on the Raspberry Pi. The second stage synchronizes Raspberry Pi's *Network Time Protocol* (NTP) with the Neo-6M GPS. This first stage is carried out by checking the GPS via UART communication on the Raspberry Pi. Table 3.1 shows the connection pins between the Raspberry Pi and the Neo-6M GPS.

Tabel 3.1. Raspberry-Pi Zero W Pin-out

Raspberry-Pi Zero W	GPS Neo-6M
Pin 2 (+5V)	VCC
Pin 6 (GND)	GND
Pin 10 (Rx)	Rx
Pin 8 (Tx)	Tx

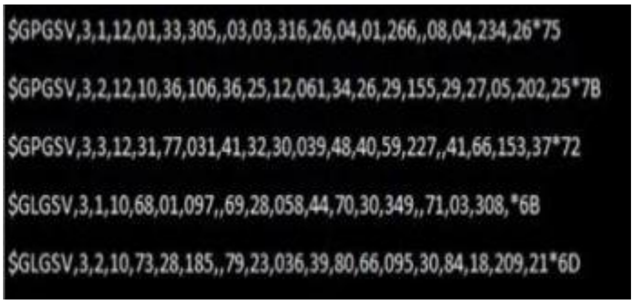

Figure 9. Screen capture of *Cat-Dev* command to the unit device.

Then, activate the UART pin on the Raspberry Pi and align between the two UART channels (*ttyAMAO* or *ttySO*). Furthermore, the baud rate alignment process is carried out between the two. Connection checking is done with the commands *sudo cat /dev/ttyAMAO* and *cgps-s*. The command results from *sudo cat /dev/ttyAMAO* are shown in Figure 9, and the command results from *cgps -s* are shown in Figure 10.

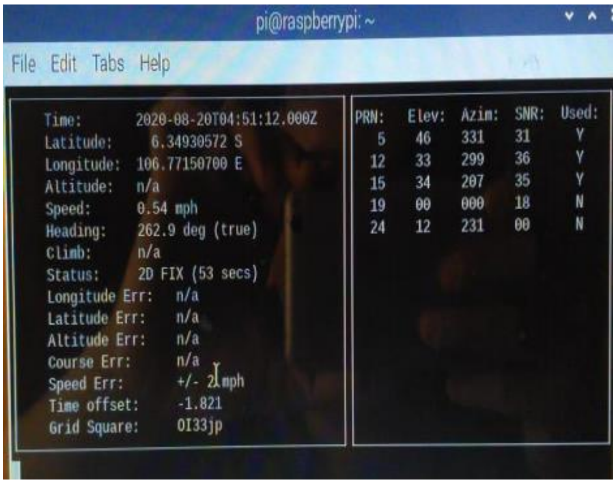

Figure 10. Screenshot of the cgps command output.

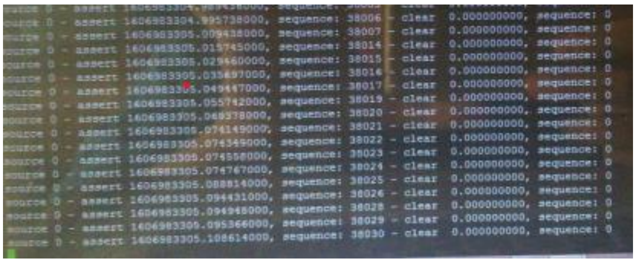

Figure 11. Timing system alignment process with *Pulse Per Second* (PPS).

Next is the second stage, namely the NTP configuration to align the timing system on the Raspberry Pi with the GPS. The latest NTP protocol is taken from the *ntp.org* page. Alignment is done by reconfiguring the Raspberry-Pi timing system with *Pulse Per Second* (PPS) on the GPS module. The screenshot of the timing system alignment is shown in Figure 11.

3.3 Mechanism of Active Seismic Module

This active seismic mode is used for the process of recording reflection seismic data, in which an artificial vibration source will be used to determine the set point. The logger device will be turned on somewhere to record data received from the ADXL355 sensor in the form of G-data into a file. The sample data can be seen in Figure 11.

Figure 11. Screen capture of sample seismic reflection data captured by the sensor.

4. CONCLUSION

Using NTP protocol synchronization, the Raspberry Pi-based seismic reflection logger instrument has successfully created eight seismic reflection logger device units. This unit works simultaneously at the same time to capture reflected seismic waves. The results of trials that have been carried out indicate that this unit can record reflected data of artificial vibration frequencies with a timing system from GPS using the NTP protocol. The seismic data obtained is then displayed on the monitor screen.

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